# Sampling the mantle transition zone regional P-waves

## Structure and sources

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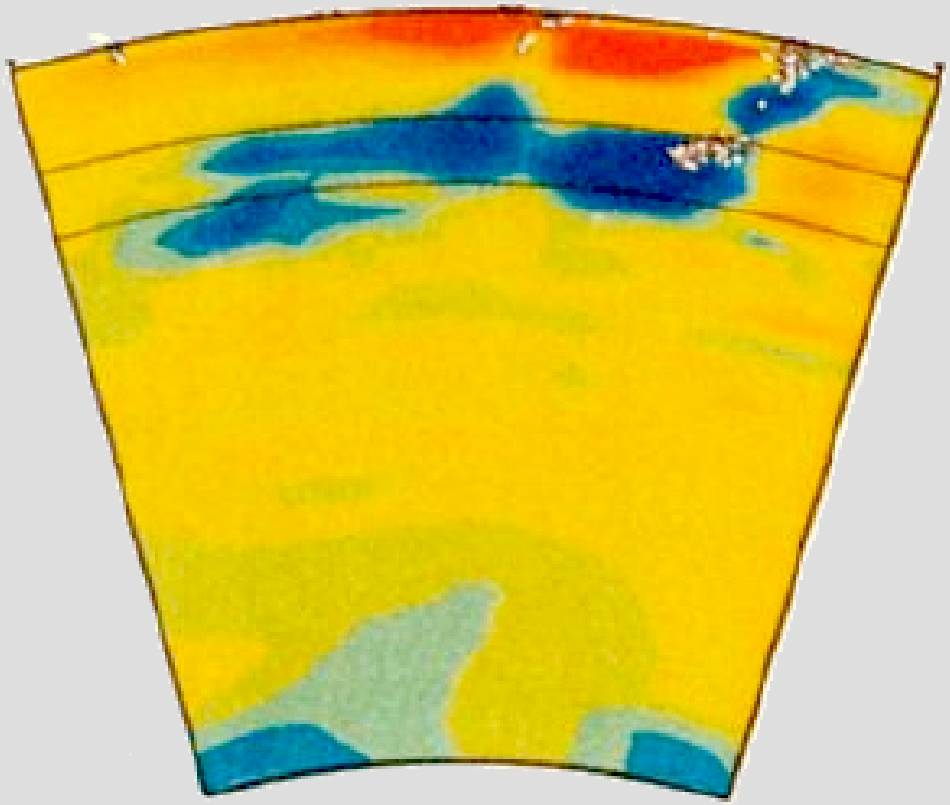
# The Mantle Transition Zone

Open questions:

- Temperature alone cannot explain the depth variations
- Mineralogical possibility of large amounts of water
- Seismic indications for low velocity zones above 660



Fukao et al. (2001)

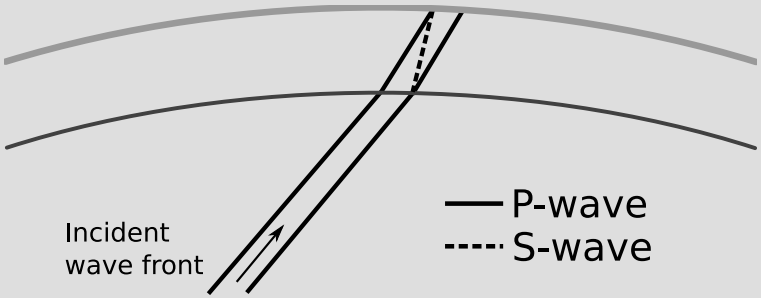
# Why study the mantle transition zone?

Questions to seismology:

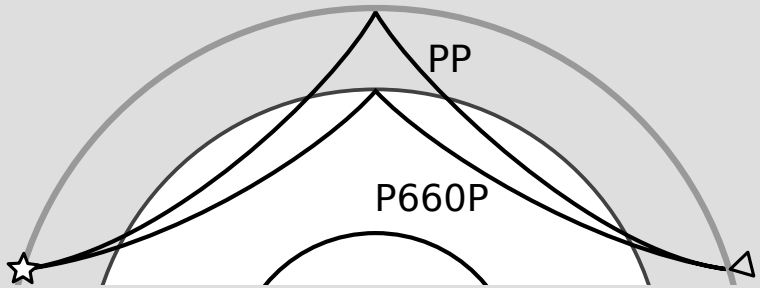
- How large are the undulations of the discontinuities?
- Do low velocity zones (melt?) exist at the discontinuities?
- Are they related to subducted slabs?

# Exploring the transition zone with *converted* waves

Receiver functions:

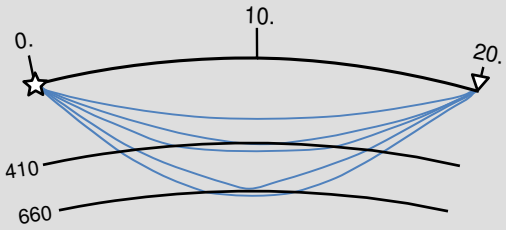


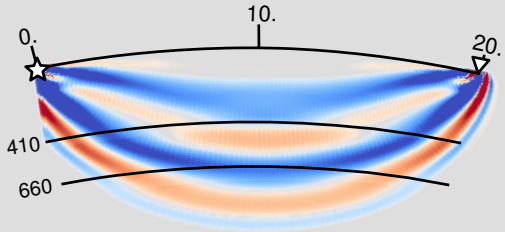

Underside reflections:

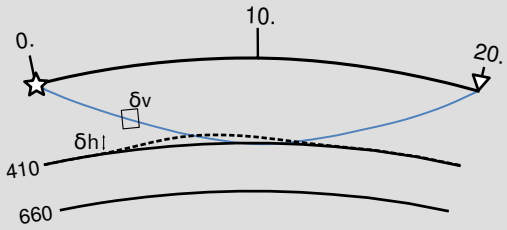


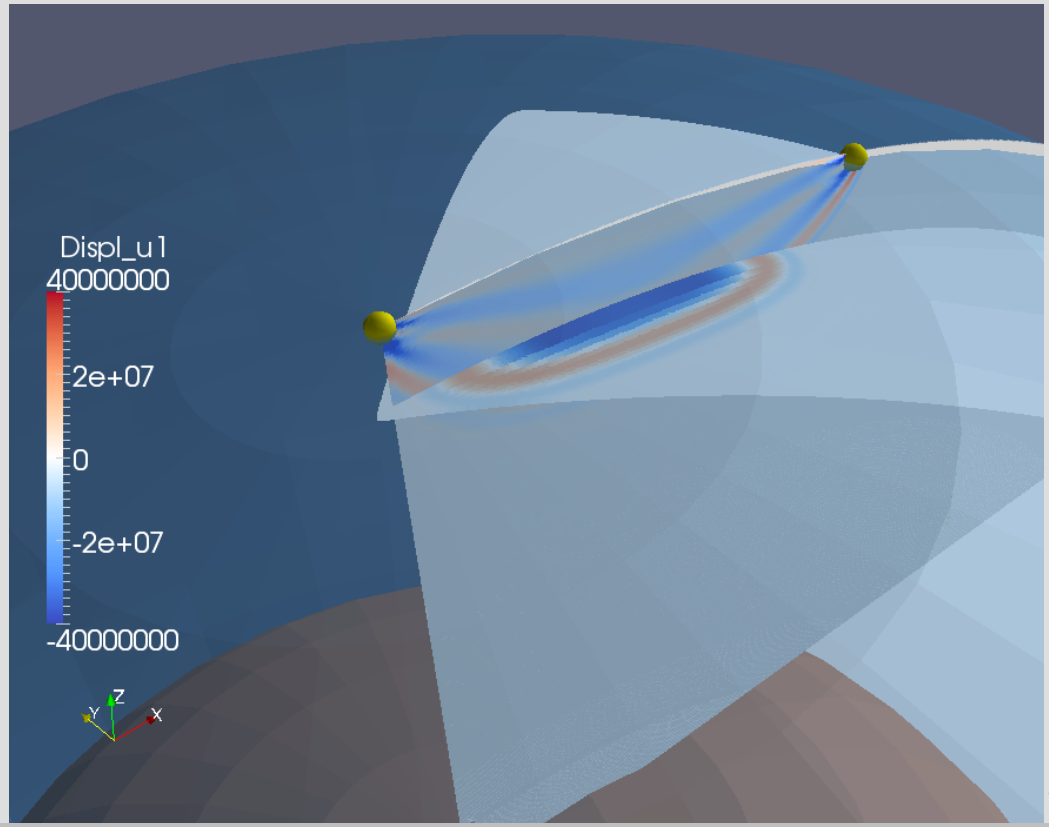

Can we really not use *transmitted* waves?

# Discontinuity kernels

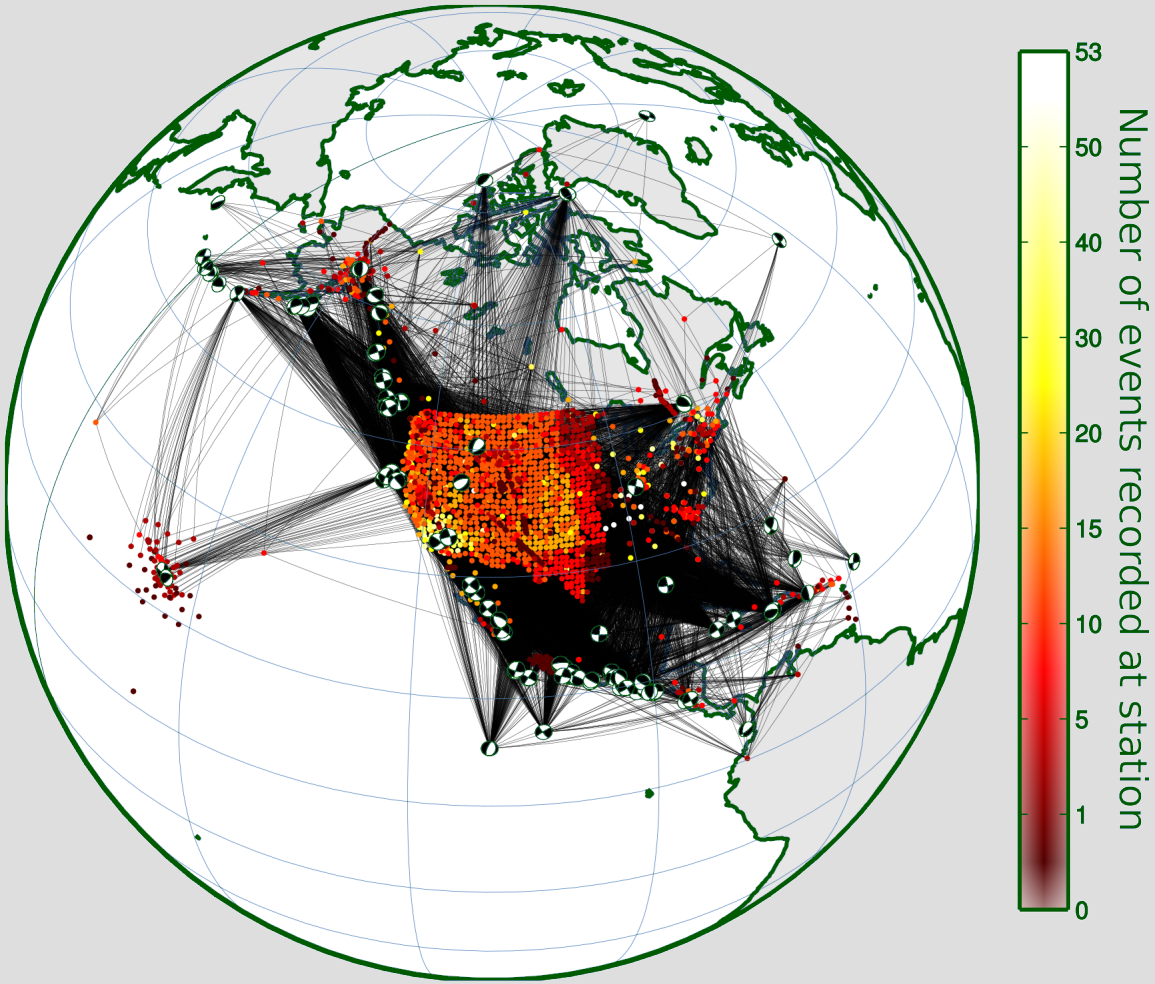


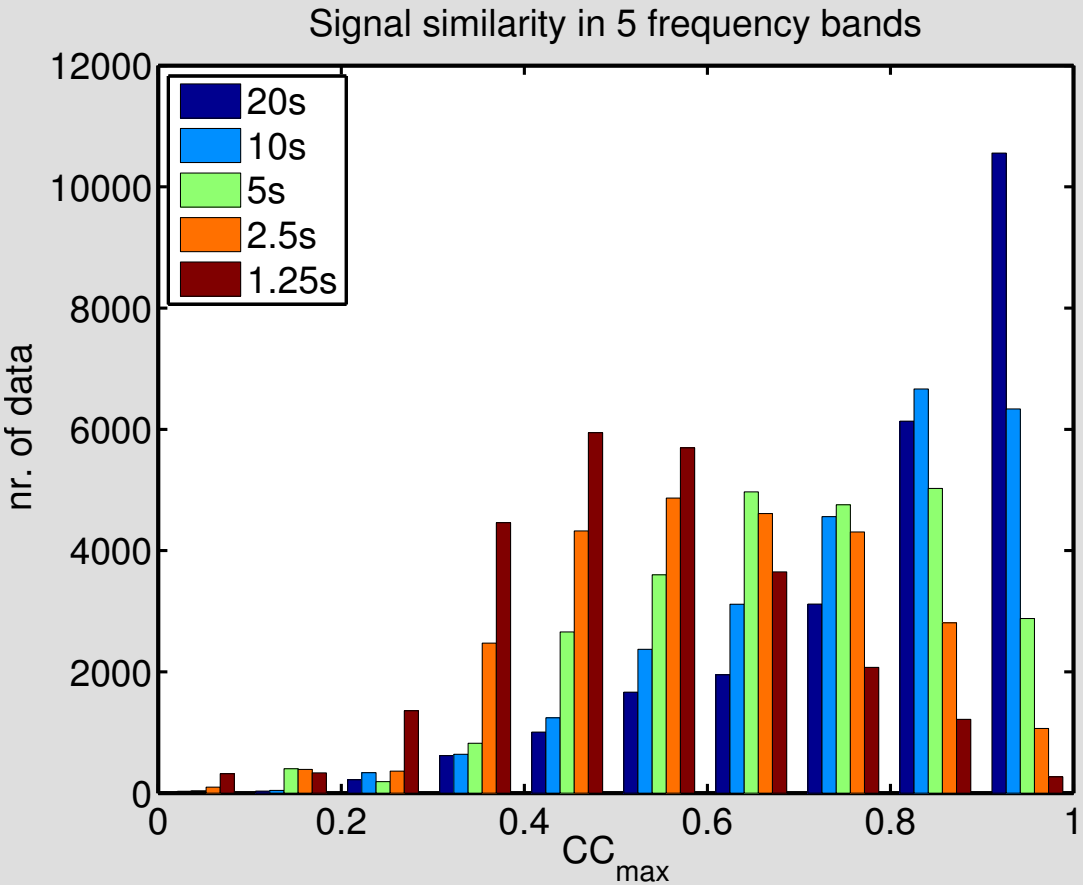



# The dataset - 92 earthquakes, 2724 stations: 25310 rays

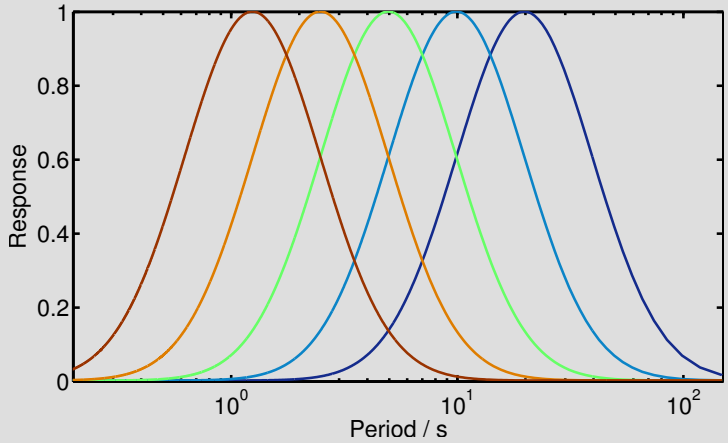



Only regional P-waves (22-35°) sampling the 660 are shown.

# Waveform fit overview

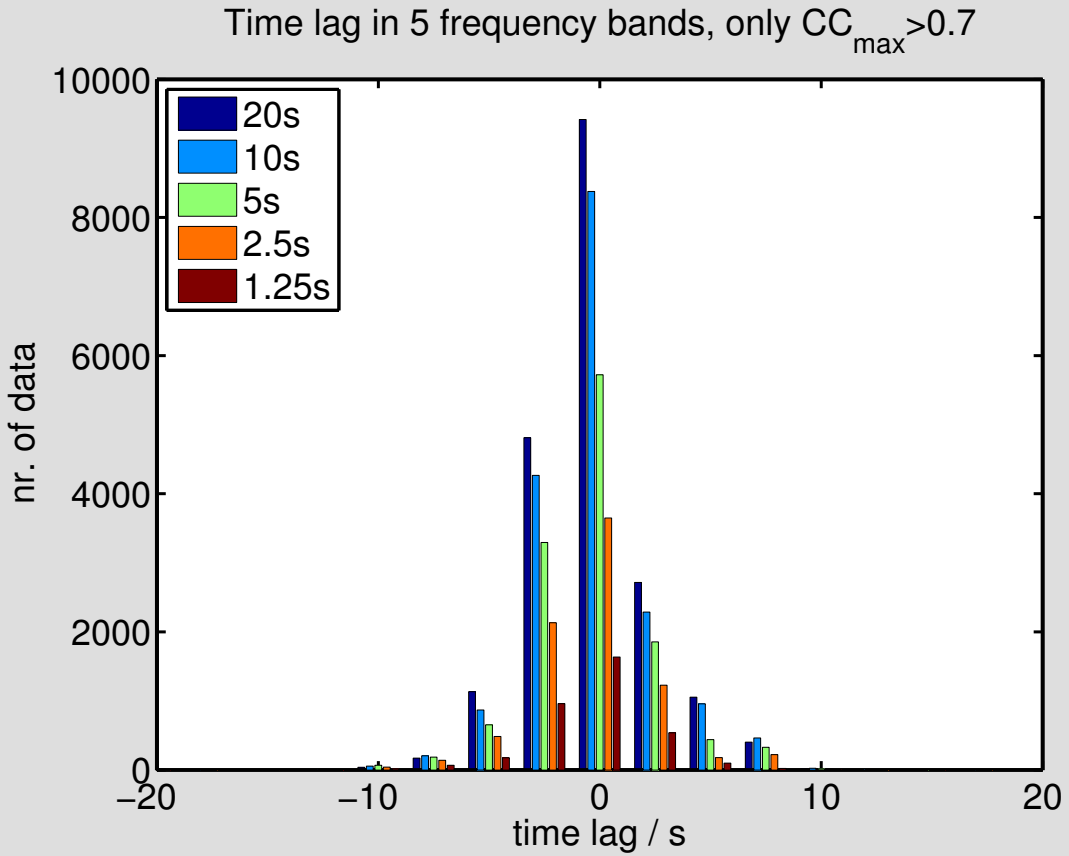



5 Gabor filters, one octave apart, one octave wide




In total: 25310 waveforms in 5 frequency bands = 126550 potential data

# The time lag: The Good and the Bad




| | |
|---|---|
| 20 s | 19774 data |
| 10 s | 17510 data |
| 5 s | 12581 data |
| 2.5 s | 8096 data |
| 1.25 s | 3523 data |
| total | 76043 data |
| out of | 126550 data |

# Source Inversion

- Catalogues vary greatly on source parameters
- For tomography we need STF estimation (which no catalogue gives)
- Bayesian inversion to get full pdfs and correlations between parameters

# Source parameters

Bayesian inversion gets prohibitively expensive for large (>12) number of parameters

| Classically: | no. of params |
|---|---|
| Source location | |
| Latitude, longitude, depth | 3 |
| Source orientation | |
| Moment tensor | 6 |
| Douple-couple | 3 |
| Source time function | |
| Rise time or "triangle duration" | 1 |
| $\Sigma$ | 7 or 10 |

# Parametrization of STF

STF is 25.6 s long and sampled with 10 Hz, so 256 samples.

- Samplewise:

$$S(t) = \sum_{k=1}^{256} \delta(k \cdot dt) \cdot a_k$$

- By Frequency:

$$S(t) = \frac{a_0}{2} + \sum_{k=1}^{128} \left( a_k \cdot \cos\left( k \frac{2\pi t}{T} \right) + b_k \cdot \sin\left( k \frac{2\pi t}{T} \right) \right)$$

- Wavelets:

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Since the bandwith is $\lesssim 1$ Hz, there are only 25 d.o.f.

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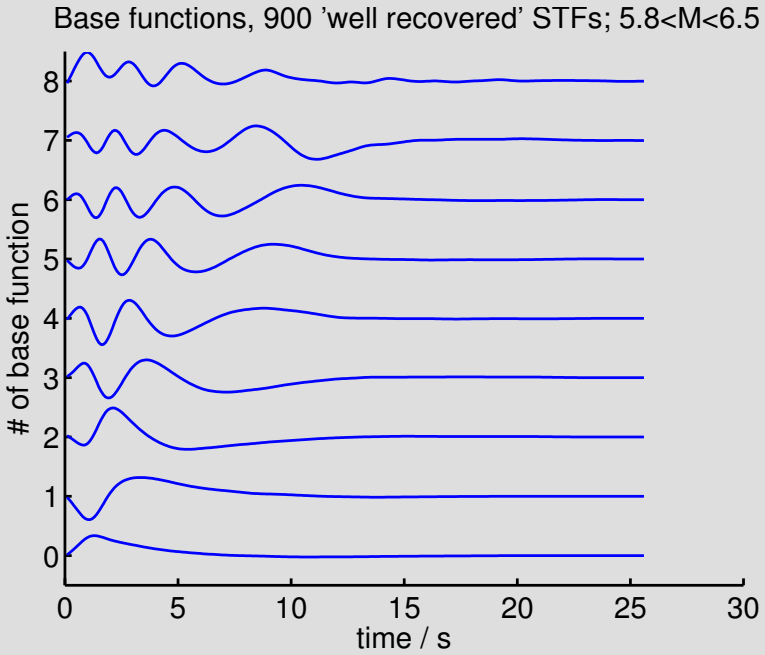
# Wavelets

- There are all kinds of wavelets - which one is suited best to our example?
- Tailored wavelets: Empirical Orthogonal Functions:
  Tries to find a base, where the first few base functions explain most of the variance in the dataset, using Principal Component Analysis
- EOF base constructed from our library of 963 “well resolved” STFs.



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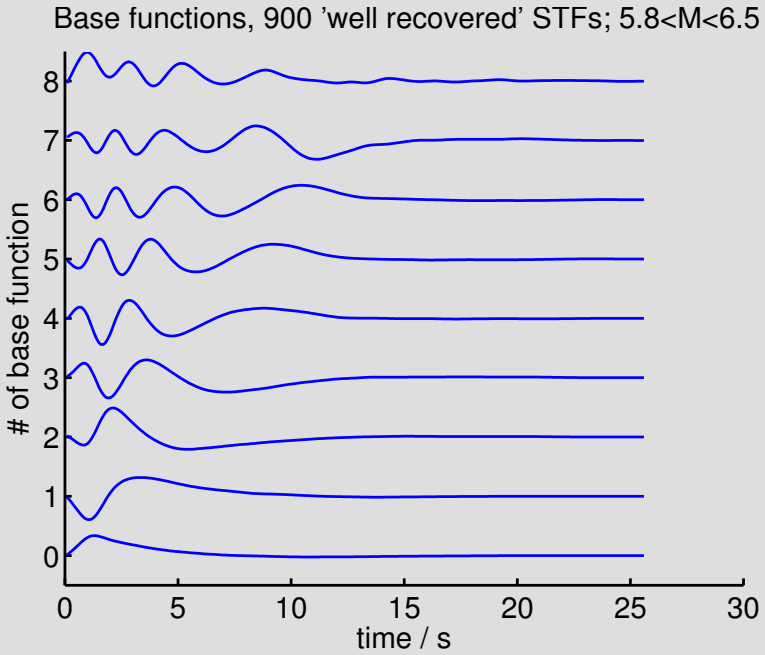

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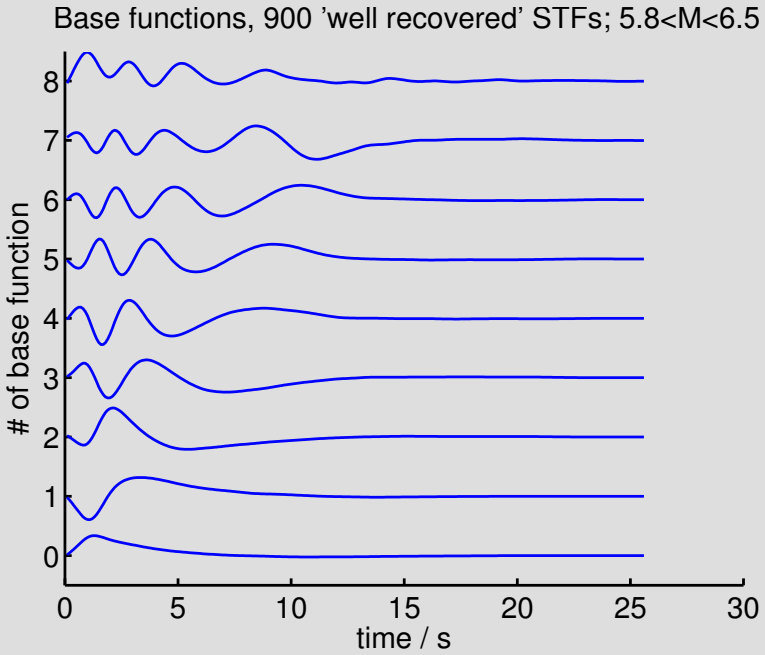


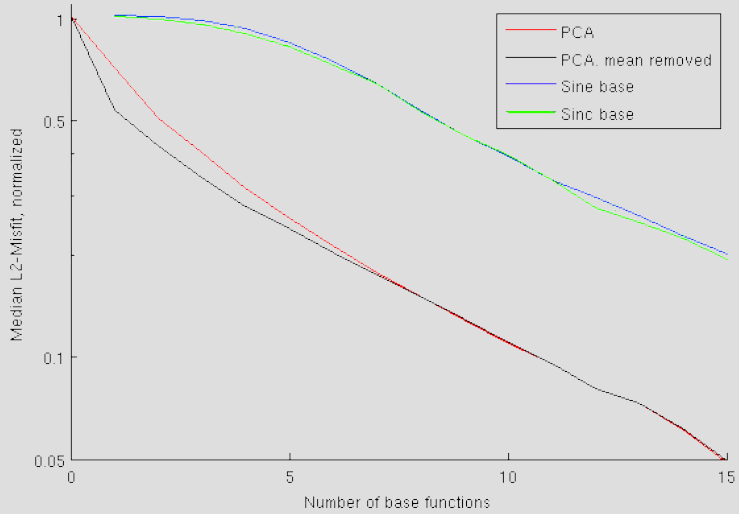
# Misfit reduction

Calculate misfit reduction for different number of parameters

- The EOF base is per definition the best base to construct the members
- But it may not be the best base for all STFs

Decision:

- Take 8 STF basefunctions (normalized misfit: 10%)
- + 4 additional parameters (depth and DC orientation)



# Bayesian inversian

Inversion is done using the Neighbourhood Algorithm (Sambridge 2000)

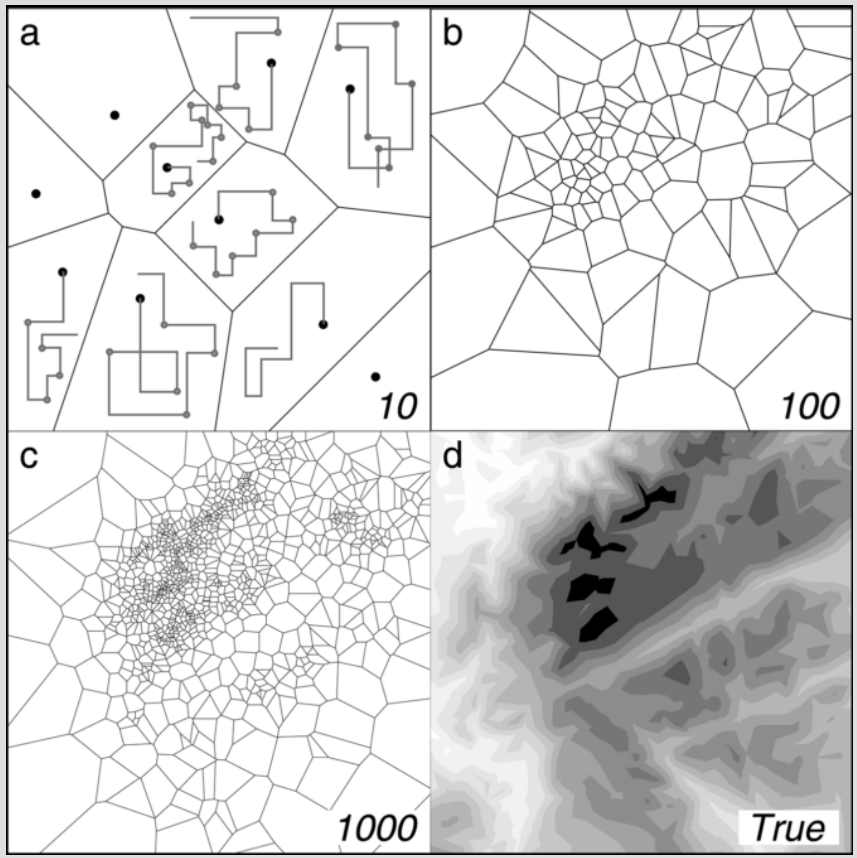
- Splits model space into voronoi cells
- Refines resolution around well fitting models

Our implementation

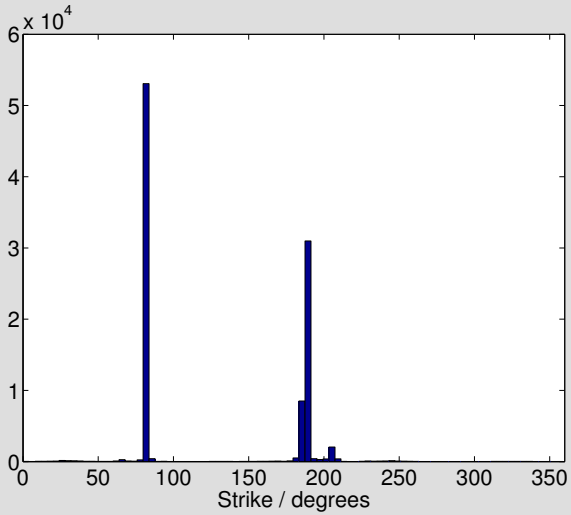
- Forward code: WKBJ
- $10^5$ forward iterations
- Misfits: CC, L1 or L2

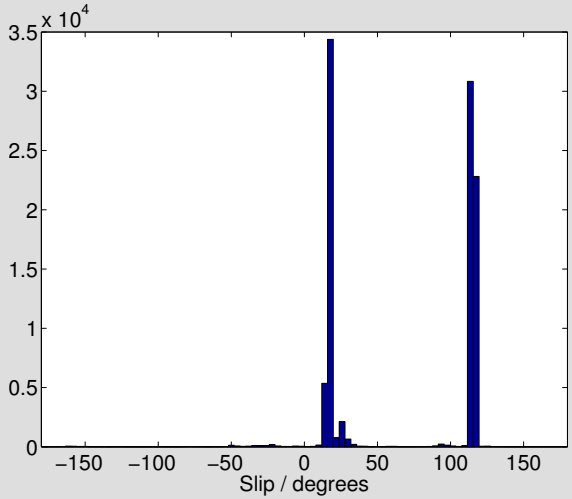
Possible drawbacks:

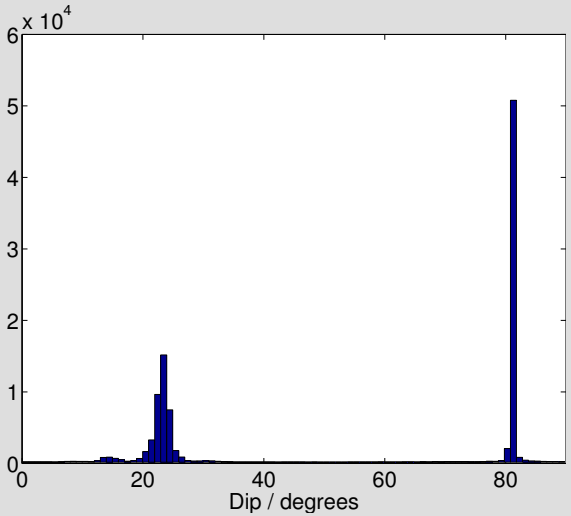
- Strike and Slip are cyclical

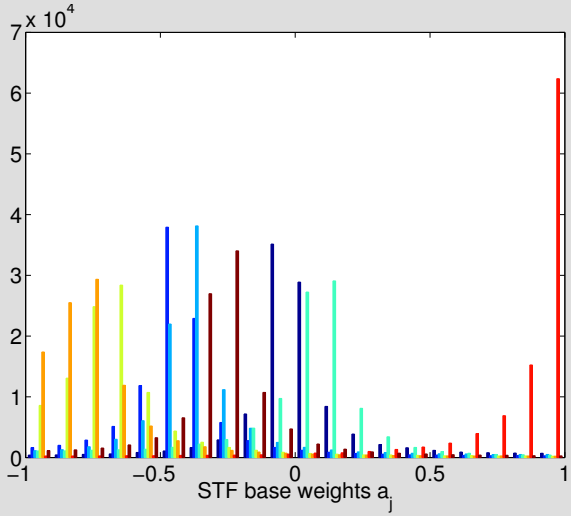


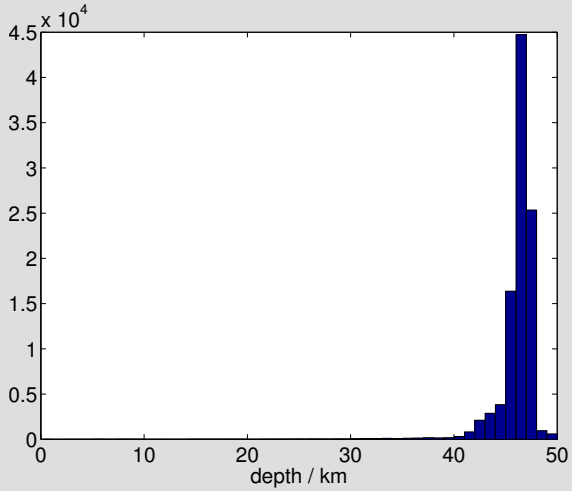
# Results (Histograms)

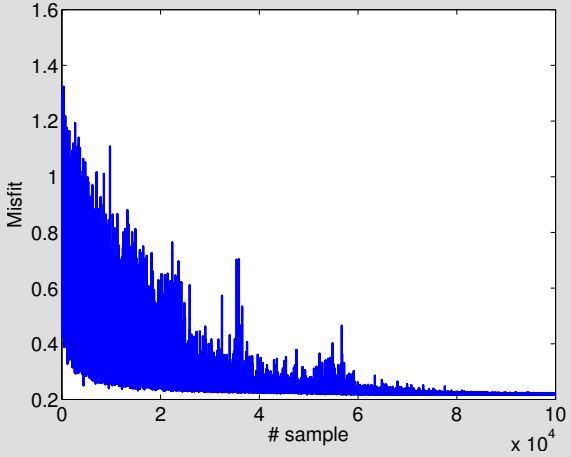


# Results (Movie)

Movie depiction of result:

- Show random samples from final set of models
- Likelihood of model to show up in movie is likelihood of it to be true (in a Bayesian sense)
- The algorithm chooses a strange soluton